

Probing cratonic lithosphere in the Paleoproterozoic: garnet peridotite xenoliths and xenocrysts from the ~1.6 Ga Zero kimberlite (Kaalvaal craton)

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Kimberlites are rare, potentially diamond-bearing igneous rocks derived from deep mantle at >150 km. They transport mantle cargo in the form of xenoliths and xenocrysts, providing unique insights into the composition and thermal structure of the Earth's interior. Zero kimberlite in the Kuruman kimberlite province represents the earliest sampling (~1.6Ga) of the Kaapvaal cratonic lithosphere and is situated near well-known diamondiferous ~120Ma Finsch (Group II kimberlite). However, Kuruman kimberlites are sub-economic despite their location in the western block of the Kaapvaal craton where much historical and active diamond mining is situated. To further understand the diamond preservation and possible destruction, we present the major and trace element compositions of garnet peridotites and garnet xenocrysts from Zero kimberlite, and their pressures-temperatures (PT) of equilibration.

Our results indicate that the lithosphere was conducive to diamond growth at 1.6Ga. A geotherm fitted through garnet xenocrysts and xenoliths records a lithosphere-asthenosphere boundary (LAB) depth of ~250 km, indicating a thicker diamond window below Kuruman at 1.6Ga than for younger adjacent kimberlites. Garnet concentrate contains a significant proportion of G10D garnets (Cr₂O₃: 9.09–10.5 wt.%), such garnet compositions correspond to the diamond stability field. Additionally, Zero peridotite xenoliths have olivine with high Mg# ranging from 92.9–94.5, indicating a strongly depleted mantle and such compositions are associated with high diamond grades^[1]. Thus, the absence of diamonds in the Zero kimberlite is unexpected.

One possible reason for the absence of diamonds in Kuruman is high-PT (4.5–7.0 GPa and 1065–1550°C) Ti-metasomatism indicated by a large proportion (20%) of Ti-rich lherzolitic G11 garnets. G11 garnets are associated with Ti-rich megacrysts and Ti-metasomatized lithologies such as sheared peridotites and are often associated with a lack of diamond preservation. The abundance of G11 garnets across a wide depth range of the Kuruman lithosphere (139–217 km) implies significant mantle refertilisation of a broad region above the lithosphere-asthenosphere boundary. Our results are consistent with the recent findings that the Ti-metasomatism by early kimberlite in the deep lithosphere can lead to partial or total dissolution of diamonds^[1].

References

1. Giuliani, A. *et al. Nat. Commun.* **14**, 1–9 (2023).